

What is claimed is:

1. A system for rehabilitation of a neuromotor disorders of a user comprising:

sensing means adapted for sensing position of one or more digits of a hand of  
5 said user to provide first sensor data;

force feedback means adapted for applying force feedback to said one or more  
digits and for measuring position of a tip of each of said one or more digits in relation to  
a palm of said hand to provide second sensor data; and

virtual reality simulation means for determining a virtual image of virtual objects  
10 movable by said user to virtually simulate an exercise adapted to be performed by said  
user, said virtual reality simulation means receiving said first sensor data and said second  
sensor data and determining performance of said user from said first sensor data and said  
second sensor data,

wherein in response to said performance of the user during said exercise said  
15 virtual reality simulation means controls determination of said virtual image and said  
force feedback means, said force feedback means being controlled to move said one or  
more digits to a position represented by said virtual image or to apply said force feedback  
to said one or more digits.

2. The system of claim 1 wherein said exercise is a range of motion exercise.

3. The system of claim 1 wherein said exercise is a speed of motion exercise.

4. The system of claim 1 wherein said exercise is a fractionation exercise of said one  
or more digits.

5. The system of claim 1 wherein said exercise is a strength exercise.

6. The system of claim 1 wherein said exercise is executed with all fingers of said  
25 one or more digits and is executed separately with a thumb of said one or more digits.

7. The system of claim 1 wherein said sensing means is a sensor glove.

8. The system of claim 7 wherein said sensor glove provides one or more  
measurements selected from the group consisting of: metacarpophalangeal (MCP) joint  
angle of a thumb of said one or more digits and a finger of said one or more digits,  
30 proximal interphalangeal (PIP) joint angle of a thumb of said one or more digits and a  
finger of said one or more digits, finger abduction and wrist flexion.

performance is measured from:

$$\max \left( \frac{\text{MCP} + \text{PIP}}{2} \right) - \min \left( \frac{\text{MCP} + \text{PIP}}{2} \right) .$$

9. The system of claim 8 wherein said exercise is a range of motion exercise and said performance is measured from:

$$\max \left( \frac{\text{MCP} + \text{PIP}}{2} \right) - \min \left( \frac{\text{MCP} + \text{PIP}}{2} \right) .$$

10. The system of claim 8 wherein said exercise is speed of motion exercise and said performance is measured from:

$$\max \left( \frac{\text{speed}(\text{MCP}) + \text{speed}(\text{PIP})}{2} \right) .$$

wherein speed(MCP) is a mean of an angular velocity of said MCP joint angle and

speed(PIP) is a mean of an angular velocity of said PIP joint angle.

11. The system of claim 8 wherein said exercise is a fractionation exercise of said one or more digits and said performance is measured from:

$$100\% \left( 1 - \frac{\Sigma \text{PassiveFingerRange}}{3 \text{ ActiveFingerRange}} \right)$$

where ActiveFingerRange is the current average joint range of the finger being moved and PassiveFingerRange is the current average joint range of the other three fingers combined.

12. The system 8 wherein said exercise is strength exercise and said performance is measured from:

$$\max \left( \frac{\text{MCP} + \text{PIP}}{2} \right) - \min \left( \frac{\text{MCP} + \text{PIP}}{2} \right) .$$

13. The system of claim 1 further comprising:

means for establishing one or more targets from said performance of said user and means for displaying said one or more targets to said user.

14. The system of claim 13 wherein said targets are displayed in real time as numerical values.

15. The system of claim 13 wherein said targets are displayed graphically as horizontal bars changing color to indicate achievement of said target.

16. The system of claim 1 wherein said exercise is a range of motion exercise and said virtual object is a window wiper moving over a fogged window wherein as said

window wiper is moved over a virtual position of said fogged window a picture is revealed at said virtual position.

17. The system of claim 1 wherein said exercise is a speed of movement exercise and said virtual object is a traffic light and a virtual hand catching a first virtual ball, wherein  
5 on a change of a signal of said traffic light said user closes said one or more digits for interacting with said virtual image to catch said first virtual ball.

18. The system of claim 1 wherein said exercise is a speed of movement exercise and said virtual object is a virtual hand and virtual butterfly, wherein said user moves said one or more digits for interacting at a predetermined speed with said virtual image to make  
10 said virtual butterfly fly away from said virtual hand.

19. The system of claim 18 further comprising a virtual opponent including a second virtual hand catching a second virtual ball, wherein if said user catches said first virtual ball before said opponent catches said second virtual ball said first virtual ball remains on said virtual hand or if said user catches said first virtual ball after said virtual opponent  
15 catches said second virtual ball said first virtual ball falls from said virtual hand.

20. The system of claim 1 wherein said exercise is a fractionation exercise and said virtual object is a piano keyboard with one or more keys, wherein one as said one or more digits is moved a corresponding said key turns a different color.

21. The system of claim 1 wherein said exercise is a strength exercise and said virtual  
20 object is virtual force feedback glove, wherein said force feedback means comprises a force feedback glove having an actuator associated with said one or more digits and as said respective actuators are depressed by said one or more digits of said user a corresponding virtual actuator on said virtual force feedback glove is filled with a color.

22. The system of claim 21 wherein said color changes depending on achievement of  
25 a percentage of a target of said performance.

23. The system of claim 1 wherein said force feedback means is a force feedback glove.

24. The system of claim 23 wherein said force feedback glove comprises one or more actuators each coupled to a respective said one or more digits.

30 25. The system of claim 24 wherein said force feedback glove further comprises one or more sensors each coupled to a respective said one or more actuators.

26. The system of claim 1 wherein said neuromotor disorder is a stroke.

27. The system of claim 1 further comprising storing means for storage of one or more of said virtual image, said first sensor data, said second sensor data and said performance.

5 28. The system of claim 27 wherein said storing means is a database.

29. A method for rehabilitation of a neuromotor disorder of a user comprising:  
determining a virtual image of a virtual object movable by said user to virtually simulate an exercise adapted to be performed by said user;  
sensing position of one or more digits of a hand of said user as said user interacts  
10 with said virtual image to provide first sensor data;

applying force feedback to said one or more digits of said hand in response to said virtual image and measuring position of a tip of each of said one or more digits in relation to a palm of said hand after said force feedback is applied to provide second sensor data;

15 determining performance of said user from said first sensor data and said second sensor data; and

updating said virtual image in response to said performance of the user during said exercise.

30. The method of claim 29 wherein said exercise is a range of motion exercise.

31. The method of claim 29 wherein said exercise is a speed of motion exercise.

20 32. The method of claim 29 wherein said exercise is a fractionation exercise of said one or more digits.

33. The method of claim 29 wherein said exercise is a strength exercise.

34. The method of claim 29 wherein said exercise is executed with all fingers of said one or more digits and executed separately with a thumb of said one or more digits.

25 35. The method of claim 29 wherein said sensing step comprises wearing a sensor glove.

36. The method claim 29 further comprising the steps of:  
establishing one or more targets from said performance of said user; and  
displaying said one or more targets to said user,  
30 wherein said virtual image is updated based on said one or more targets.

37. The method of claim 29 wherein said exercise is a range of motion exercise and said virtual object is a window wiper moving over a fogged window wherein as said window wiper is moved over a virtual position of said fogged window a picture is revealed at said virtual position.

5 38. The method of claim 29 wherein said exercise is a speed of movement exercise and said virtual object is a traffic light and a virtual hand catching a first virtual ball, wherein on a change of a signal of said traffic light said user closes said one or more digits for catching said first virtual ball.

39. The method of claim 29 further comprising a virtual opponent including a second  
10 hand catching a second virtual ball, wherein if said user catches said first virtual ball before said opponent catches said second virtual ball said first virtual ball remains on said hand or if said user catches said first virtual ball after said virtual opponent catches said second virtual ball said first virtual ball falls from said virtual hand.

40. The method of claim 29 wherein said exercise is a fractionation exercise and said  
15 virtual object is a piano keyboard with one or more keys, wherein one as said one or more digits is moved a corresponding said key turns a different color.

41. The method of claim 29 wherein said exercise is a strength exercise and said virtual object is a virtual force feedback glove.

42. The method of claim 29 wherein said force feedback step comprises wearing a  
20 force feedback glove on said hand.

43. The method of claim 42 wherein said force feedback glove comprises one or more actuators each coupled to a respective said one or more digits.

44. The method of claim 43 wherein said force feedback glove further comprises one or more sensors each coupled to a respective said one or more actuators.

25 45. A method for rehabilitation of a stroke patient comprising:

determining a plurality virtual images each virtual image simulating an exercise adapted to be performed by said patient;

sensing position of one or more digits of a hand during interaction of said patient with each said virtual image to provide first sensor data;

30 optionally applying force feedback to said one or more digits of said hand of said patient in response to one of said virtual images and measuring position of a tip of each

of said one or more digits in relation to a palm of said hand if said force feedback is applied to provide second sensor data;

determining performance of said user from said first sensor data or said second sensor data; and

5 updating said plurality of virtual images in response to said performance of the user during said respective exercises.

46. A method for rehabilitation of a stroke patient comprising:

determining a plurality virtual images each virtual image simulating an exercise selected from the group consisting of a range of motion exercise, a range of speed exercise, fractionation exercise and a strength exercise;

10 sensing position of one or more digits of a hand during interaction of said patient with each respective said virtual image simulating said range of motion exercise, said range of speed exercise, and said fractionation exercise to provide first sensor data;

applying force feedback to said one or more digits of said hand of said patient in response to said virtual image simulating said strength exercise and measuring position of a tip of each of said one or more digits in relation to a palm of said hand after said force feedback is applied to provide second sensor data;

determining performance of said patient from said first sensor data or said second sensor data; and

20 updating said plurality of virtual images in response to said performance of said patient during said respective exercises.

47. The method of claim 46 wherein said interaction of said patient with each respective said virtual image is repeated a predetermined number of times for each exercise.

25 48. The method of claim 46 wherein said force feedback is repetitively applied to said patient a predetermined number of times.

49. A system for rehabilitation of a stroke patient comprising:

means for determining a plurality virtual images each virtual image simulating an exercise selected from the group consisting of a range of motion exercise, a range of speed exercise, fractionation exercise and a strength exercise;

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means for sensing position of one or more digits of a hand during interaction of said patient with each respective said virtual image simulating said range of motion exercise, said range of speed exercise, and said fractionation exercise to provide first sensor data;

5 means for applying force feedback to said one or more digits of said hand of said patient in response to said virtual image simulating said strength exercise;

means for measuring position of a tip of each of said one or more digits in relation to a palm of said hand of said patient after said force feedback is applied to provide second sensor data;

10 means for determining performance of said patient from said first sensor data and said second sensor data; and

means for updating said plurality of virtual images in response to said performance of the user during said respective exercises.

50. A distributed system for rehabilitation of a stroke patient comprising:

15 a rehabilitation site comprising sensing means adapted for sensing position of one or more digits of a hand of said patient to provide first sensor data, force feedback means adapted for applying force feedback to said one or more digits of hand and for measuring position of a tip of each of said one or more digits in relation to a palm of said hand to provide second sensor data, and virtual reality simulation means for determining at least  
20 one virtual image of one or more virtual objects movable by said patient to virtually simulate an exercise adapted to be performed by said user, said virtual reality simulation means receiving said first sensor data and said second sensor data and determining performance data of said patient from said first sensor data and said second sensor data, said virtual reality simulation means controlling determination of said at least one virtual  
25 image and controlling said force feedback means in response to said performance of the patient during said exercise;

a data storage site for storing said virtual images and said performance data; and

a data access site for remotely reviewing said virtual images and performance data.

51. The distributed system of claim 50 wherein said rehabilitation site, said data storage site and said data access site are connected to each other through an Internet connection.

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